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Comparison of the seasonal frequency of SFERICS over Western Europe and the number of thunderstorm hours in the British Isles

S F G Farmer,

October 1981

Met O 9 (Special Investigations)
Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ

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Comparison of the seasonal frequency of SFERICS over Western Europe and the number of thunderstorm hours in the British Isles

S.F.G. Farmer, Met O 9 (October 1981)

This note gives some preliminary results of an analysis of the seasonal frequency with which SFERICS are reported over Western Europe and the adjacent sea areas which include parts of the Western Mediterranean and Adriatic, North East Atlantic, North Sea and the Southern Baltic. As an aid to the interpretation of these results the seasonal frequency of thunderstorm hours reported by surface observers in the United Kingdom has also been compiled.

1. SFERICS analysis

SFERIC observations from the routine CRDF Thunderstorm Location network are archived on magnetic tape. The basic observations are made during the 10 minutes immediately preceding the clock hour and in the 10 minutes before the half hour. The observations just before the clock hour are made using a network of stations in the United Kingdom, with Beaufort Park, Easthampstead acting as the selector station on most occasions. This is known as the "U.K. Run". During the 10 year period for which data has been analysed the "U.K. Run" was maintained hourly throughout the 24 hours (with some minor exceptions). The observations made just before half past the clock hour are based on a network of stations in the Mediterranean. This is known as the "Mediterranean Run". Observations from these stations are normally only made during the day (0530 to 2030 GMT).

For the present analysis only the "U.K. Runs" were used as this gave nearly equal weight to each hour of the day. The period analysed was the 10 years from 1967 to 1976 inclusive. From March 1969 onwards there were no observations made at 00 and 02 GMT. During the period January 1967 to February 1969 some 00 GMT observations have not been included in this preliminary analysis due to a minor programming error. At all the other times there are a few occasions on which an observation run was not made due to technical difficulties and there are also a few occasions on which additional observations were made immediately after the main run. During the 10 year period analysed there were observation runs at 98% of all possible observing hours (excluding 00 and 02 GMT).

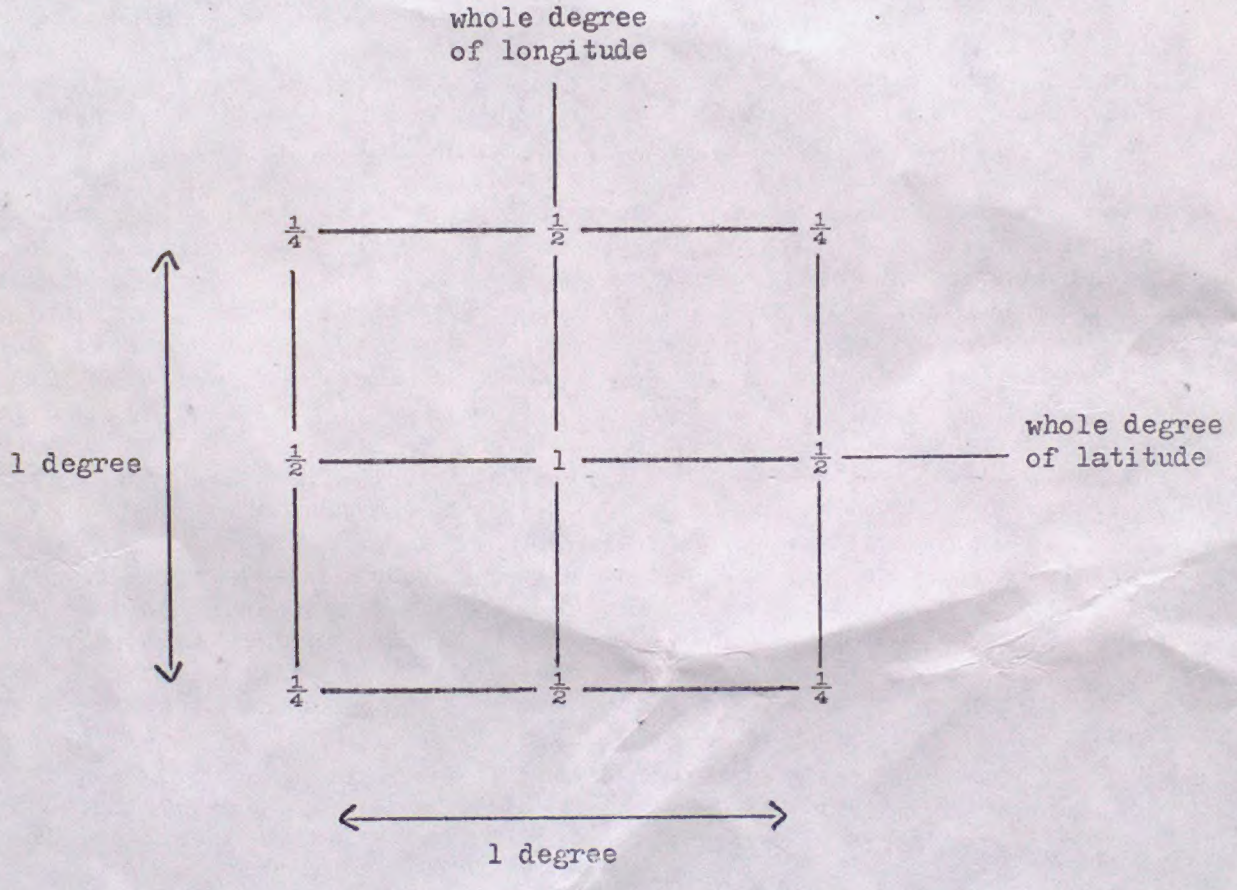
The area analysed is that lying between latitude 30.5 and 62.5 degrees North and longitudes 15.5 degrees West to 15.5 degrees East. Beaufort Park acted as selector station on 99.5% of the runs analysed.

During an observation period the geographical position of each SFERIC fix chosen by the Selector station is recorded. At the end of the observation period a plot of all the fixes is examined and adjacent fixes combined. The position of each thunderstorm or group of thunderstorms is then reported as a SFERIC location (to a precision of $\frac{1}{2}$ a degree of latitude and $\frac{1}{2}$ a degree of longitude) together with the combined number of fixes. It is this information which has been stored on the archive magnetic tapes. In addition the attenuator setting for each run is archived but these have not been used in the present analyses.

An initial analysis was conducted to examine the distribution of SFERICS over England and Wales for the period 1967 to 1976. The total number of SFERIC fixes was plotted at each intersection of lines of latitude and longitude at $\frac{1}{2}$ degree intervals for each month of the year and the whole year. An examination of these plots showed there was a very marked tendency for high values to occur on the lines of latitude

and longitude corresponding to whole numbers of degrees and low values on the half degree lines. This appeared to indicate a bias on the part of the observers to report an integral number of degrees. As a result it was thought necessary to smooth the data.

For the analysis of the number of SFERIC fixes over Western Europe reported in this note the data have been smoothed over "one degree squares". A "one-degree square" has been defined as the area bounded by two lines of latitude and two lines of longitude which are one degree apart. The centre of each "one-degree square" chosen has a latitude and longitude which is an integral number of degrees. The "one-degree squares" do not overlap but the total number of SFERIC fixes is conserved. The number of SFERIC fixes at 9 adjacent points have been smoothed using the weightings indicated below.



Seasonal maps of the frequency of SFERIC fixes for 10 years for Western Europe have been plotted and appear in Figures 1-4. The annual map is Figure 5.

The first thing to be noted from the annual map is the very large range in the SFERIC fixes. Off the North West of Scotland the value is about 10 while over the Alps the values exceed 4000. An approximately logarithmic contouring interval was chosen for this annual map with contours drawn at 10, 30, 100, 300, 1000 and 3000 (SFERIC fixes in a "one-degree square" in a 10 year period). The annual map shows two main maxima over the Alps and Pyrenees with values generally decreasing northwards. More insight into the make-up of this annual map can be gained by considering the four seasonal maps in turn.

The contours drawn on the seasonal maps are 10, 25, 50, 100, 200, 500, 1000, 2000 (SFERIC fixes in "one-degree square" in 10 seasons). In addition a 700 contour has been used on the winter and spring maps and a 3000 contour on the summer map to define the positions of the maxima more accurately.

In the winter (December, January and February) the main maxima are over the Western Mediterranean and just west of Italy. A band of higher values lies along the Portuguese coast and the North coast of Spain. Weaker maxima occur in the English Channel, Bristol Channel, off the north west coast of Scotland and off the Norwegian coast. All these maxima occur over the sea where the warmer waters act as a source of sensible heat. Orographic uplift along the windward shores of Norway, Scotland, Ireland, Southwest England and Portugal may also play a role.

In the winter all of Scandinavia and Eastern Europe has a very low number of SFERICS with the region of low values extending westwards to France. Very low values occur along the east coast of England and Scotland and over Ireland. There is also a very pronounced minimum over central Spain. The main regions of low values over continental Europe occur where the land surfaces are cold and often snow covered in winter. The marked minimum over Spain is interesting as this demonstrates the limited penetration of convective cloud inland in spite of the fact that the Iberian peninsula is surrounded by relatively warm water. The minima along the east coast of England and Scotland and over Ireland are also caused by low land surface temperatures, cold waters in the North Sea and Irish Sea and limited penetration of convective cloud inland from the warmer waters which lie to the west and south west of the British Isles.

In the spring (March, April and May) the effect of increased solar heating over the land especially during May is already evident. The main maxima occur over Southern France, Northern Italy and Yugoslavia. A separate maximum occurs over central England and there is even a weak maximum over Ireland.

On the other hand there is a very marked minimum over the cold waters of the central North Sea, the Irish Sea and Celtic Sea and the whole of the open Atlantic lying to the north and west of the British Isles. The sea surface temperatures generally reach their lowest values during the spring.

In the summer (June, July, August) the solar heating of the land reaches a maximum and the incidence of thunderstorms reaches its highest level over nearly all parts of Northern Europe. The two main maxima occur over the Alps and the Eastern Pyrenees. There are also weaker maxima over central England and Ireland.

In Southern Europe minima occur over the Southern Mediterranean and off the south west coast of Spain due to the predominantly anticyclonic conditions which prevail. In Northern Europe low values persist over the central North Sea and Irish Sea. The open Atlantic north and west of the British Isles is also an area of low values. However this area does not have uniformly low values and there are several weak maxima and minima. This may simply reflect inadequate sampling over this area during the analysis period with the values reflecting the effects of a small number of thundery synoptic situations. At other seasons of the year the values in this area are generally more uniform.

In the autumn (September, October, November) there is a transition from thunderstorms developing predominantly over the land in summer to thunderstorms developing predominatly over the sea in winter. The main maxima occur over the Mediterranean to the south of the Gulf of Lions, west of Italy and over the north east Adriatic but

high values also occur over the adjacent land. There is also a minor maximum over the Bordeaux region of France adjacent to the warm waters of the Bay of Biscay. The highest values in the British Isles are found in South East England. It should be noted that there is a region of higher values extending from the Cherbourg peninsula through the Straits of Dover and the southern North Sea to Denmark. The sea surface temperatures in the southern North Sea are near their maximum values. The persistent region of low thunderstorm activity in the central North Sea which is present at all other seasons is not apparent in the autumn.

Regions of minimum SFERIC activity occur over central Spain, Eastern Europe and Scandinavia. The open Atlantic to the north and west of the British Isles has very low values. It is noticeable that the pattern in this area is much smoother in autumn than it is in summer.

To summarise the findings from these initial analyses it is clear that the seasonal patterns of SFERICS show a number of features which can be directly related to other parameters. In particular SFERICS in autumn and winter frequently occur over areas of warm sea water. Conversely SFERICS do not normally occur over regions of cold sea water such as the Irish Sea in spring and the central North Sea in winter, spring and summer. There is also very little SFERIC activity over the Southern Mediterranean in the summer in spite of high sea surface temperatures due to the predominantly anticyclonic conditions. Over the land maximum SFERIC activity occurs in mountainous areas such as the Alps and Pyrenees in the summer when there is strong solar heating. Conversely SFERIC activity is low in winter over land which is cold and perhaps snow covered, and far enough inland from relatively warm seas for convective clouds to be unlikely to penetrate. In the autumn when the land is still warm a fairly high incidence of SFERIC activity may be experienced in coastal regions bordering a warm sea such as the Bordeaux region of France and South East England.

2. Thunderstorm hours analyses

Climatological returns of hourly observations of surface weather are recorded on archive magnetic tapes for over 50 stations in the United Kingdom. In addition there are over 20 stations with 3-hourly observations of surface weather on magnetic tape. One of the parameters recorded is the present weather in coded form. These hourly and 3-hourly observations of present weather have been used to compile frequency tables of the number of thunderstorm hours.

All the present weather code figures which are used to describe thunderstorms are given below together with abbreviated definitions.

WMO CODE 4677 Present weather code figure (ww)	Abbreviated definitions
17	Thunderstorm but no precipitation at time of observation.
29	Thunderstorm (with or without precipitation) at the station during the preceding hour.
91-94	Thunderstorm during preceding hour but not at the time of observation (Precipitation at time of observation)
95-99	Thunderstorm with precipitation at the time of observation.

A "thunderstorm hour" has been defined as an observation time at which any of the present weather code figures listed above was reported. This includes both thunderstorms at the time of observation and thunderstorms during the preceding hour. However it does not include occasions when only distant lightning was seen. The audible range of thunder in normal circumstances is about 10 miles (16 kms).

The period analysed was the 10 years from 1971 to 1980. There were 45 stations with complete or nearly complete hourly data for this period. The shorter records of Benson and Abingdon were combined as were the records of Boulmer and Acklington. The distribution of these stations together with the percentage of data available for analysis are shown in Figure 6. In order to improve the analysis in some data sparse areas 20 stations with 3-hourly data on magnetic tape were also analysed. The positions of these stations and percentage of data available for analysis is also shown in Figure 6. A method was devised for estimating the total number of thunderstorm hours at these stations from the 3-hourly data.

The monthly and annual frequency of thunderstorm hours was compiled for each station. These frequencies were corrected to allow for any periods of missing data. On the whole these corrections were small. The seasonal frequencies were then calculated. The seasons were defined as the 3 month periods December to February (winter), March to May (spring), June to August (summer) and September to November (autumn).

Seasonal maps of the frequency of thunderstorm hours in 10 years for the United Kingdom have been plotted and appear in Figures 7-10. The annual map is Figure 11.

In winter the highest number of thunderstorm hours are observed along the coasts of South West England, and South Wales, western and northern Scotland. Conversely low values are observed in central and eastern districts of England and Scotland and also over the northern Irish Sea.

In spring the position is reversed with far more thunderstorms being reported from inland stations. The main maximum occurs over the East Midlands and East Anglia with a secondary maximum over Southern Scotland. Much lower values occur in all coastal regions except the English Channel. The lowest values occur over Northern Scotland and the northern Irish Sea. Weak minima occur over the moister land of the Fens and Upper Thames Valley.

In summer there is again a marked contrast between the high values inland and lower values on the coasts. The main maximum is again located over the East Midlands and East Anglia with a secondary maximum over Southern Scotland. Much lower values are reported in all coastal districts except the coasts of South and East England from the Isle of Wight to the Humber. The lowest values occur in coastal districts of Northern Scotland. Weak minima again occur over the Fens and Thames Valley.

In the autumn the combined effect of warm land surfaces in the early autumn and warm seas in the late autumn gives rise to a pattern with less coherence than at the other seasons. The main maximum occurs over South East England with a weaker maximum over East Anglia. Fairly high values also occur over the East Midlands and parts of South West England and Wales. There is also a region of higher values over the warmer waters of the northern Irish Sea. In contrast much of North and East Scotland has low values.

In the annual map the separate contributions of the individual seasons are combined with the influences of the summer predominating. The main maximum occurs over East Anglia and the East Midlands with a weaker maximum over South East England. There is also a weak maximum over the Southern Uplands of Scotland, with higher values in West Scotland compared with East Scotland. Coastal values are generally lower with the effects of the Severn Estuary and the Solway Firth being noticeable. Inland there are lower values over the Fens and the upper Thames Valley.

3. Comparison of the frequency of SFERICS and thunderstorm hours

A comparison of the seasonal maps of the frequency of occurrence of SFERICS and thunderstorm hours over the United Kingdom shows that they are in good qualitative agreement. The positions of the main maxima and minima and the general disposition of the patterns are broadly the same.

The differences between the patterns may have arisen from several different causes.

a. different analysis periods

b. different geographical sampling areas (SFERICS smoothed over "one-degree squares"; thunder observed within audible range of the station)

c. different observing periods (SFERICS for 10 mins; thunderstorms for up to one hour by inclusion of preceding hour thunderstorms)

d. different sampling techniques (SFERICS are a selected sample from a large Service Area; thunder occurring within audible range of a station is nearly always recorded)

e. the effect of attenuator setting on SFERIC detection (not allowed for in this analysis)

f. the heirarchy of coding present weather may sometimes preclude a thunderstorm in the preceding hour being reported

g. the number of thunderstorm hours was estimated for 3-hourly data stations

h. the SFERIC analysis is based on only 22 hours of data in each day for most of the analysis period.

In view of these differences it is not surprising that small scale features on the thunderstorm hour maps are not reproduced on the SFERIC maps.

An attempt has been made to establish a quantitative relationship between the number of SFERICS and the number of thunderstorm hours. A comparison area within the United Kingdom was defined. This consisted of 48 "one degree squares" centred on the intersections of whole degrees of latitude and longitude. The area which has been considered is shown in Figure 12. About two thirds of the "one degree squares" are based on land points. The remaining third should be considered as coastal. The mean number of sferic fixes in each of these "one degree squares" was tabulated for each season. The corresponding number of thunder hours at the grid point at the centre of each "square" was interpolated from the seasonal maps. The mean number of thunder hours (T) has been plotted against the mean number of sferic fixes (S) in Figure 13. An inspection of the four seasonal plots suggested that a power law relationship of the form

$$T = aS^b$$

might exist between T and S for each season. A linear regression of $\log_e T$ as a function of $\log_e S$ was performed for each season separately and all seasons combined. The results are given below.

TABLE 1

Analysis area : United Kingdom

Season	a	b	Correlation Coefficient of $\log_e$ T as function of $\log_e$ S
Summer	2.03	0.51	0.89
Autumn	1.15	0.51	0.84
Winter	0.68	0.60	0.58
Spring	0.59	0.62	0.92
All seasons combined	0.78	0.68	0.87

The lines corresponding to the fitted equations are plotted in Figure 13. A Student's t test showed that the correlation was significant at the 0.1% level in summer, autumn and spring and at the 1% level in winter. The lower value of correlation coefficient in winter arises from the overall smaller values of T and S in winter and the greater scatter (on a logarithmic scale). Individual outliers in the winter distribution can be identified with the Orkneys (where the number of sferic fixes is much less than in the Shetlands for instance) and the East coast of Scotland and the Wash (where the number of thunder hours recorded is very low). A statistical test of the difference in the value of the power law exponent b between winter (0.60) and spring (0.62) showed these were not significantly different. On the other hand the value of b for summer (0.51) and spring (0.62) are significantly different at the 1% level. This probably reflects a change of relationship between the seasons due to a difference in the mean attenuator setting. The attenuator setting will be higher generally in summer than winter. (This effect has not been allowed for in this preliminary analysis.)

The correlation coefficient for all the seasons combined is highly significant at a probability level of less than 0.1%.

The equations which have been derived apply only to the United Kingdom. In order to establish whether they have wider application a second area was chosen for an independent verification. The choice of the area to be considered was limited by the availability of hourly and 3-hourly present weather data from which the frequency of thunderstorm hours could be derived. The area chosen was West Germany. Data for 17 stations were available. For 7 of these stations there were hourly climatological data mostly for the 10 year period 1967-1976. For the other 10 stations there were 3 hourly data for the 6 year period 1974-79. These data had been obtained via the normal telecommunication channels and were extracted from the Synoptic Data Bank. For all of these stations approximately 95% of the available data had been received. In this analysis the actual number of thunderstorm hours at the station has been used (rather than the number of thunderstorm hours interpolated at a grid point) and this has been correlated with the mean number of sferic fixes in a "one-degree-square" centred on the station interpolated from the seasonal sferic maps. The mean number of thunder hours (T) has been plotted against the mean number of sferic fixes (S) in

Figure 14. A linear regression of $\log_e$ T as a function of $\log_e$ S was again performed for each season and for all seasons combined.

TABLE 2

Analysis area : West Germany

Season	a	b	Correlation Coefficient of $\log_e$ T as function of $\log_e$ S
Summer	10.57	0.33	0.61
Autumn	5.16	0.15	0.17
Winter	0.98	-0.03	0.03
Spring	2.10	0.54	0.52
All seasons combined	1.75	0.65	0.90

The lines corresponding to the fitted equations are plotted in Figure 14. The correlation coefficient is significant at the 1% level in summer and the 10% level in spring. However in autumn and winter there is apparently no significant statistical correlation. In comparison with the analysis for the United Kingdom these results are disappointing. However several possible reasons for the poorer correlation during the separate seasons can be identified.

a. Only 17 stations have been analysed and for more than half of these the data were 3-hourly for a 6 year period only. The analysis period for the 3-hourly data (1974-79) is different from the hourly data (1967-76).

b. It is very noticeable that the overall range of T and S in each season is much smaller (on a logarithmic scale) than for the United Kingdom. This probably arises because the United Kingdom analysis included both coastal and inland grid points. For West Germany on the other hand very few stations are near the coast. Most of the stations can be considered as representative of inland continental conditions. The sample of stations analysed is more homogeneous than in the United Kingdom and there are therefore smaller differences between the frequency of thunderstorms at the stations to be exploited.

c. The number of sferics and the number of thunderstorms over the European Continent in winter is very small. The scatter of values (on a logarithmic scale) is large during this season.

d. Very minor differences may have arisen because all the "one-degree-squares" are not of equal area. There is also a small difference in the analysis method between the United Kingdom (where the number of thunder-

storm hours was interpolated at a grid point) and West Germany (where the number of sferic fixes was interpolated for a "one-degree-square" centred on the station).

In marked contrast to the results obtained for the individual seasons, the equation fitted to the data for all the seasons combined is most encouraging. The correlation coefficient is 0.90. This is highly significant at a probability of less than 0.1%. It should also be noted that the value of the power law exponent b is very similar to the value obtained from the United Kingdom analysis. The value of a (1.75) for West Germany is however more than twice the value for the United Kingdom (0.78). This difference corresponds to a smaller number of sferic fixes reported over West Germany for each thunderstorm hour than for the United Kingdom. This may be a reflection of the differences due to distance or propagation effects. However it is clear that the same type of power law relationship appears to hold over both the United Kingdom and West Germany

4. Conclusions

(1) Seasonal maps of the distribution of sferic fixes over Europe and adjacent sea areas have been produced for a 10 year period. The distribution of sferics is coherent. Qualitatively there is good agreement between the areas of maximum and minimum sferic activity and topographical features, warm and cold sea areas and land surfaces which would be expected to influence the frequency of thunderstorm development.

(2) Seasonal maps of the number of thunder hours over the United Kingdom have been produced. A comparison has been made of these thunder hour maps and the frequency of sferic fixes. These are in broad qualitative agreement in spite of a number of known differences between the observational methods.

(3) Quantitative relationships have been established between the mean number of thunder hours and the mean number of sferic fixes for each season over the UK. The correlation found is highly significant in all seasons except winter. Similar relationships have been derived for a more limited area in West Germany, but the correlation is only significant in spring and summer. This is thought to be due in part to the limitations of the data available. When the results for all seasons are combined a similar type of power law relationship is found to exist in both the United Kingdom and West Germany.

(4) Further work on the relationship between the number of thunder hours and sferic fixes will have to be directed towards establishing the influence of attenuator setting, distance and propagation conditions. As attenuator setting is subject to both diurnal and seasonal changes it will be necessary to establish the influence of each of these effects. When all the effects are understood it should be possible to infer the number of thunder hours over the sea areas adjacent to Western Europe from the frequency of sferic fixes.

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Fig 1 Total number of SFERIC fixes in 10 winter seasons (Dec., Jan., Feb.)

Fig 2 Total number of SFERIC fixes in 10 spring seasons (Mar., Apr., May)

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Fig 4 Total number of SFERIC fixes in 10 autumn seasons (Sep., Oct., Nov.)

Fig 5 Total number of SFERIC fixes in 10 years.

Fig 6 Percentage of surface observations in period 1971-1980 available for analysis.

Fig 7 Total number of hourly observations with thunder reported at the station in 10 winter seasons (Dec., Jan., Feb.)

Fig 8 Total number of hourly observations with thunder reported at the station in 10 spring seasons (Mar., Apr., May)

Fig 9 Total number of hourly observations with thunder reported at the station in 10 summer seasons (Jun., Jul., Aug.)

Fig 10 Total number of hourly observations with thunder reported at the station in 10 autumn seasons (Sep., Oct., Nov.)

Fig 11 Total number of hourly observations with thunder reported at the station in 10 years.

Fig 12 Areas used for comparison of thunder hours and sferic fixes.

Fig 13 Comparison of seasonal number of thunder hours and sferic fixes for the United Kingdom.

Fig 14 Comparison of seasonal number of thunder hours and sferic fixes for West Germany.

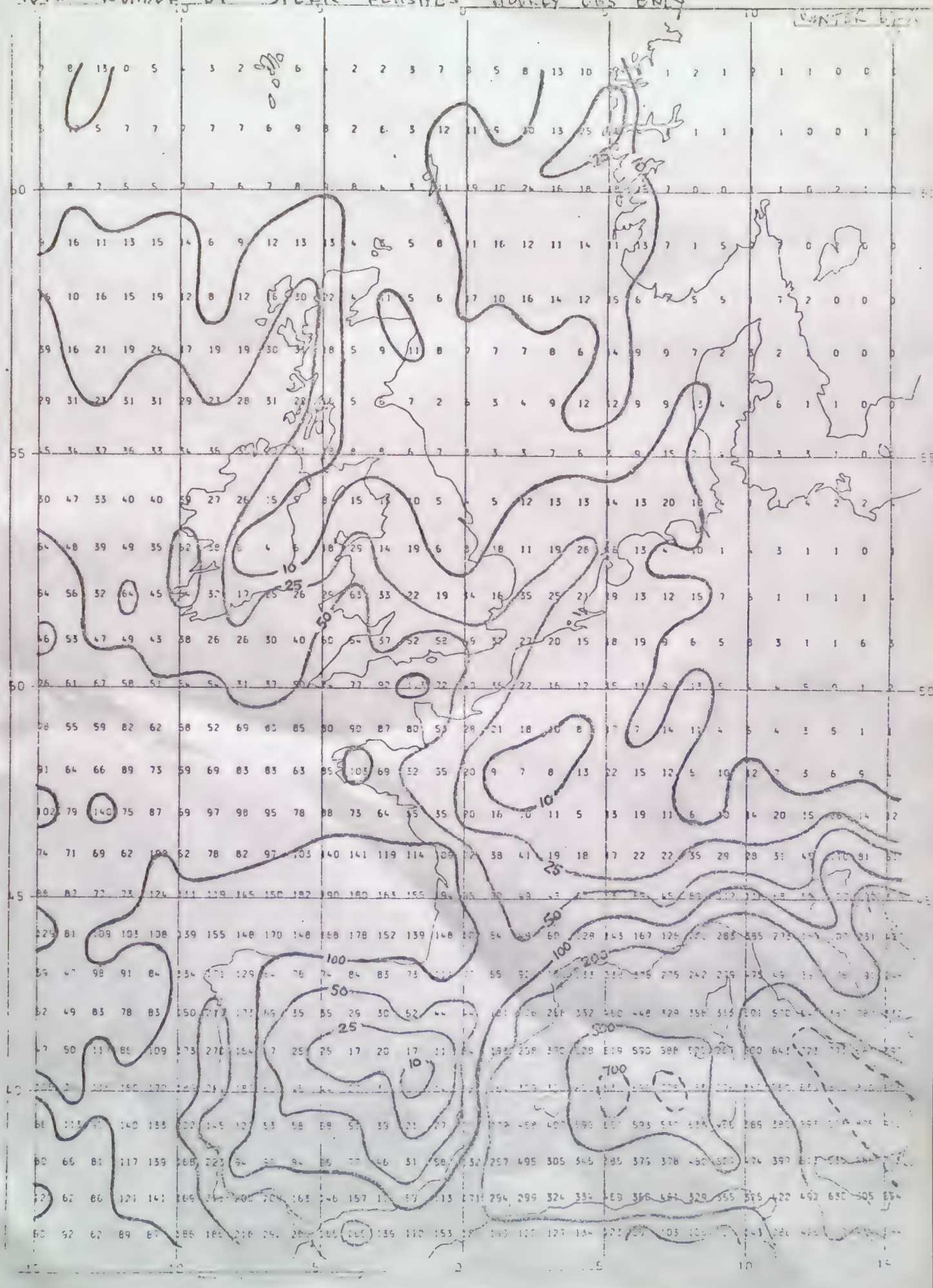


Fig 1 Total number of SFERIC fixes in 10 winter seasons (Dec., Jan., Feb.)

Fig 2 Total number of SFERIC fixes in 10 spring seasons (Mar., Apr., May)

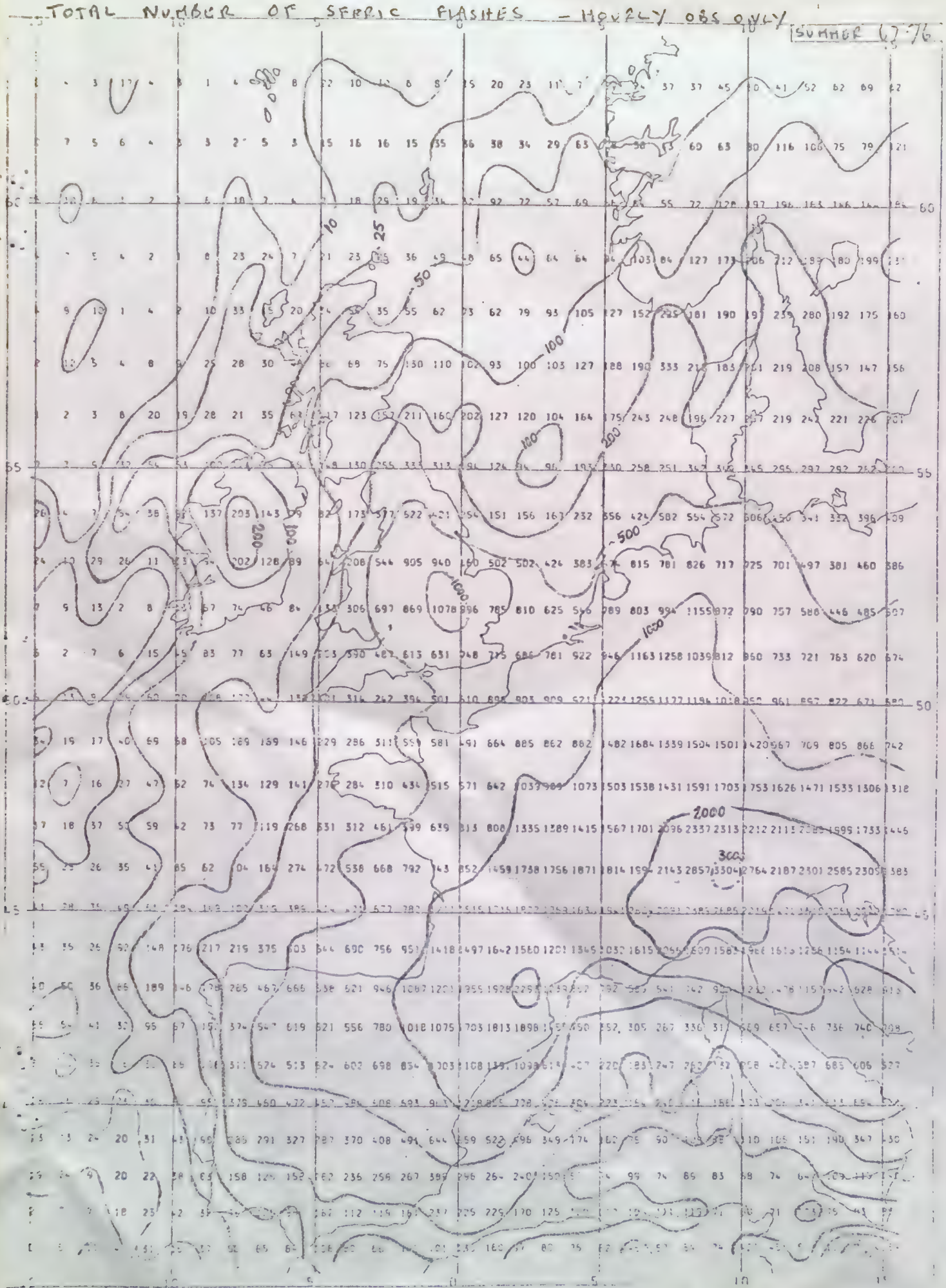


Fig 3 Total number of SFERIC fixes in 10 summer seasons (Jun., Jul., Aug.)

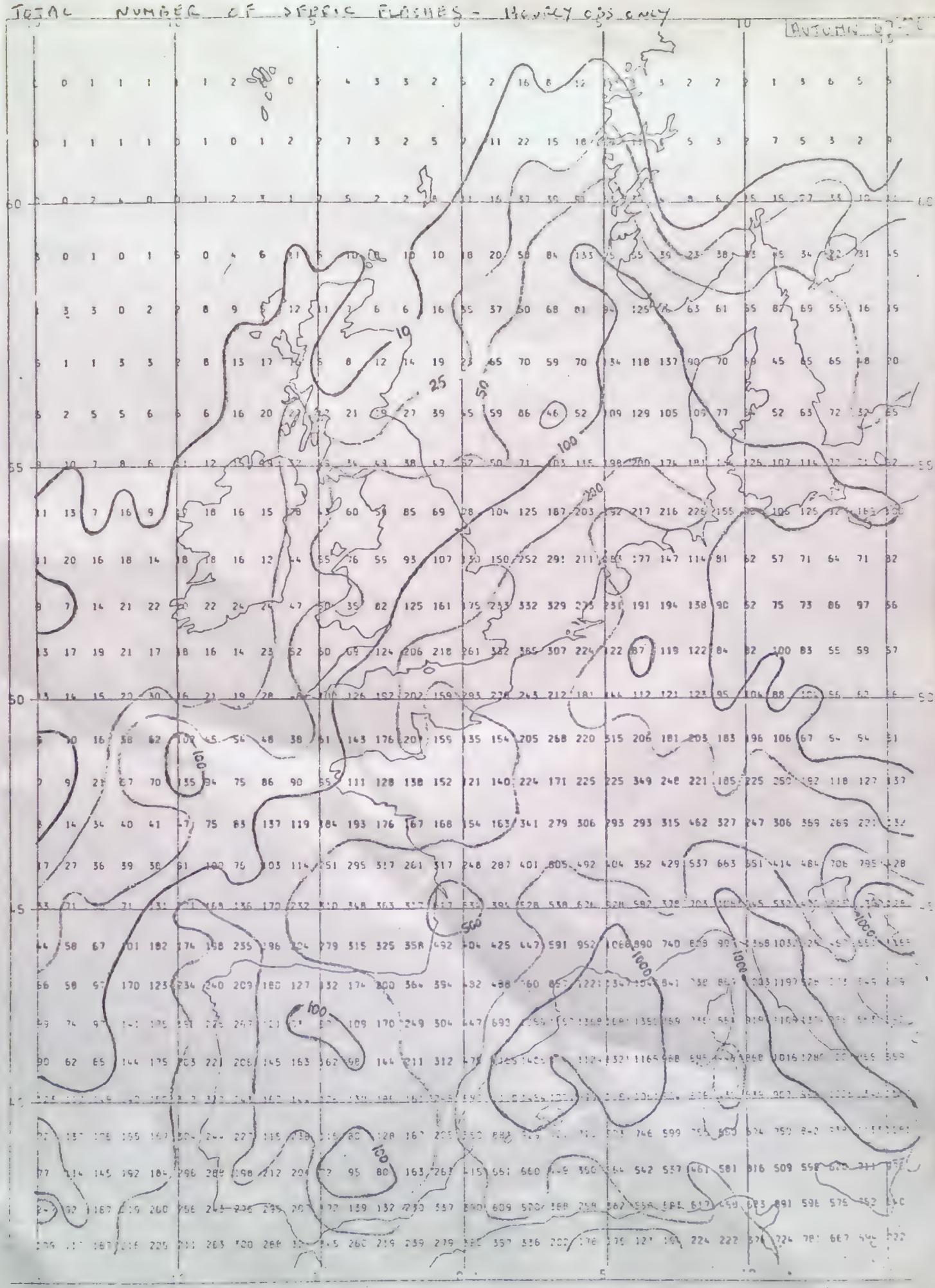


Fig 4 Total number of SFERIC fixes in 10 autumn seasons (Sep., Oct., Nov.)

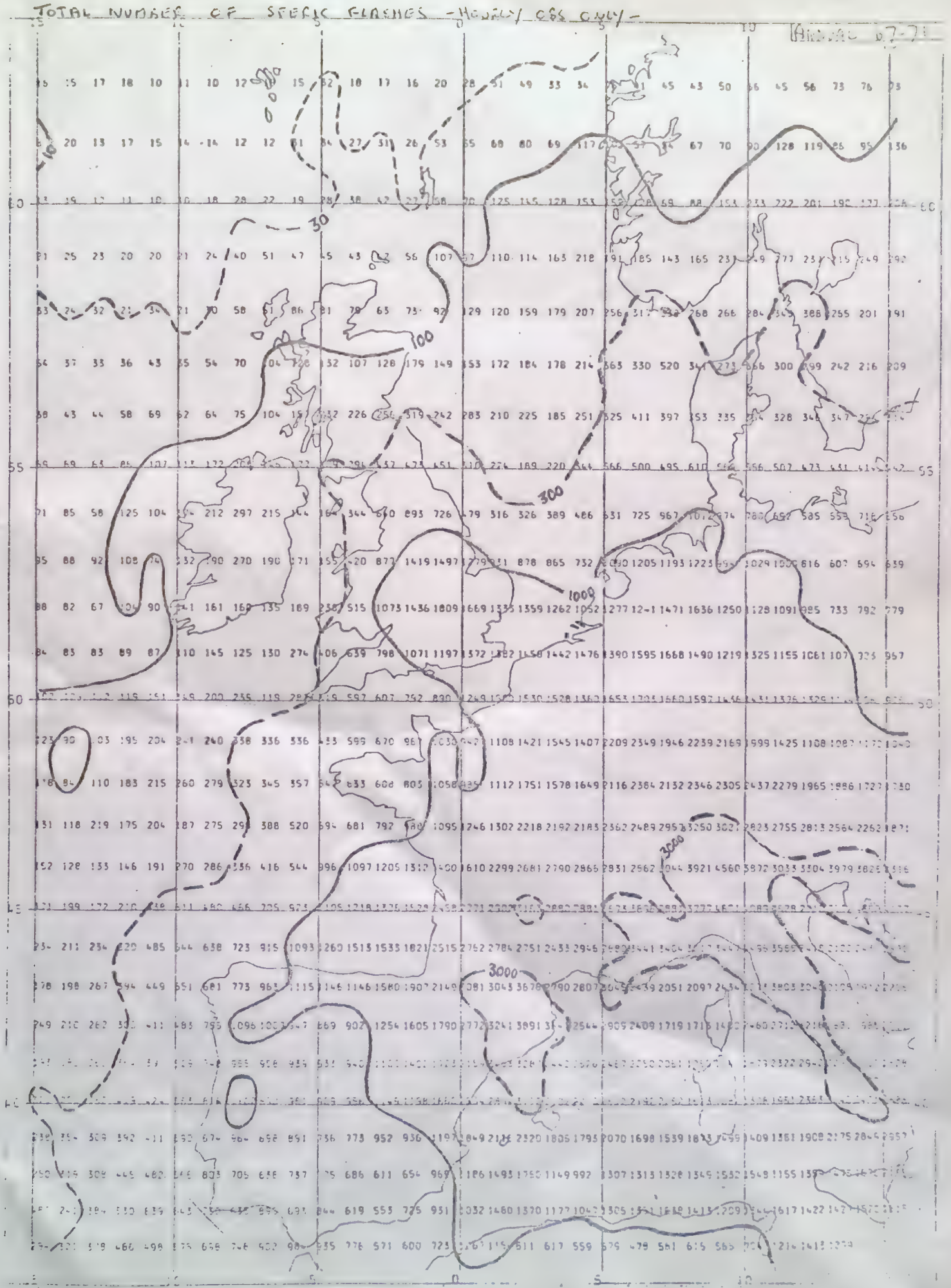


Fig 5 Total number of SFERIC fixes in 10 years.

PERCENTAGE OF DATA IN PERIOD 1971-1980 AVAILABLE FOR ANALYSIS.

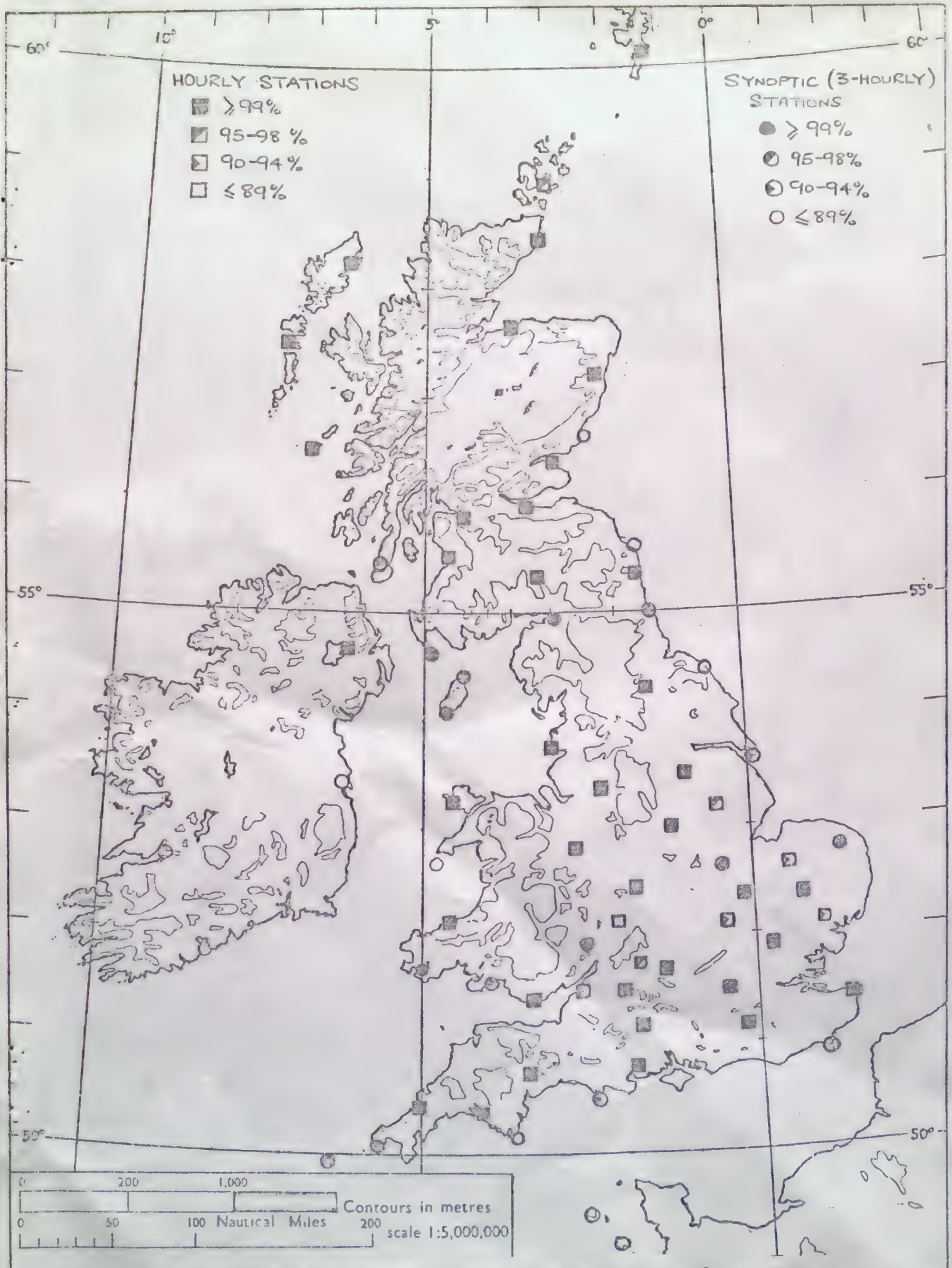


Fig 6 Percentage of surface observations in period 1971-1980 available for analysis.

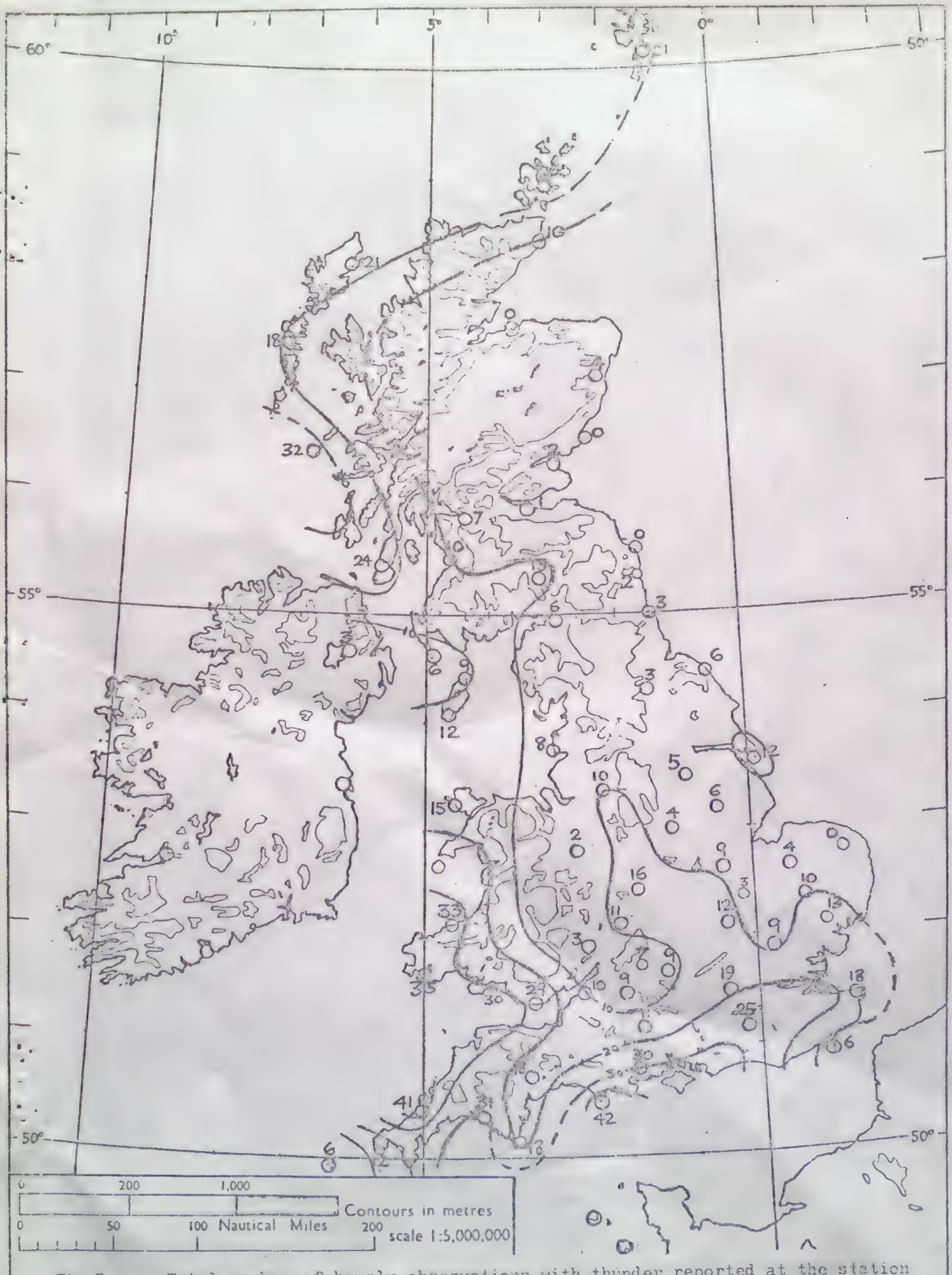


Fig 7 Total number of hourly observations with thunder reported at the station in 10 winter seasons (Dec., Jan., Feb.)

TOTAL NUMBER OF HOURLY OBSERVATIONS WITH THUNDER REPORTED AT THE STATION IN 10 SPRING SEASONS (MAR., APR., MAY)

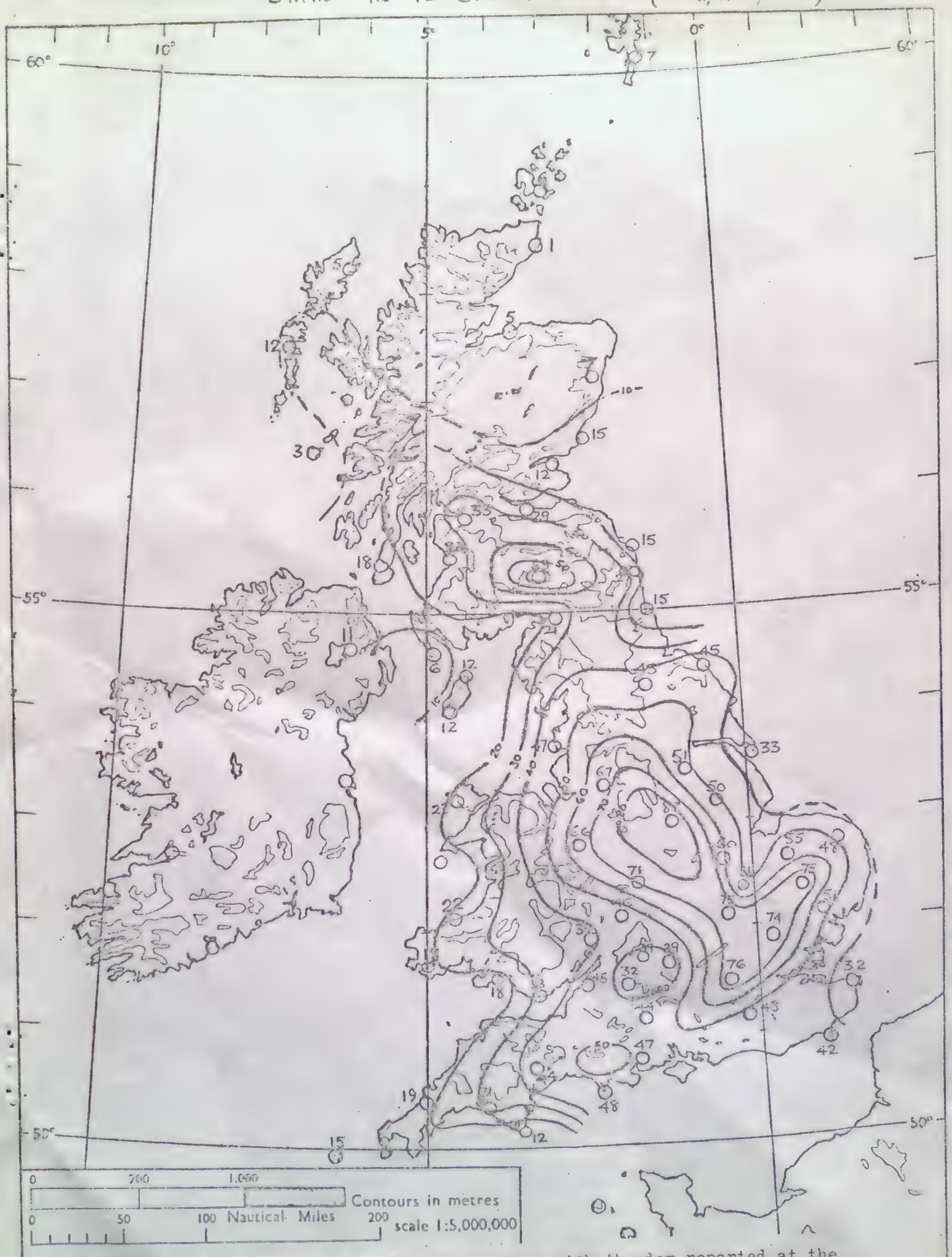


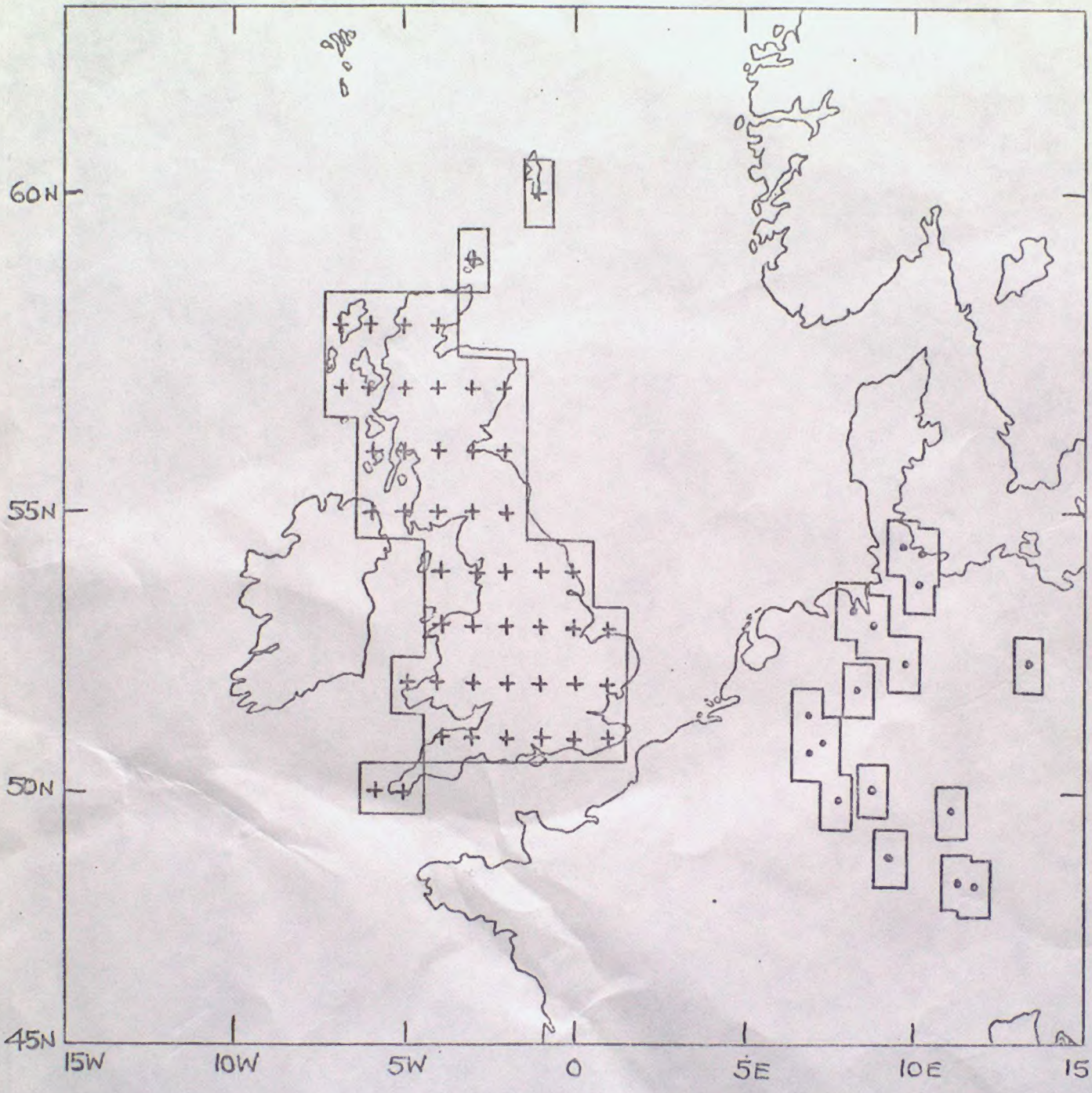
Fig 8 Total number of hourly observations with thunder reported at the station in 10 spring seasons (Mar., Apr., May)

Fig 9 Total number of hourly observations with thunder reported at the station in 10 summer seasons (Jun., Jul., Aug.)

Fig 10 Total number of hourly observations with thunder reported at the station in 10 autumn seasons (Sep., Oct., Nov.)

TOTAL NUMBER OF HOURLY OBSERVATIONS WITH THUNDER REPORTED AT THE STATION IN 10 YEARS

Fig 11 Total number of hourly observations with thunder reported at the station in 10 years.



AREAS USED FOR COMPARISON OF THE MEAN NUMBER OF HOURS THAT THUNDER WAS HEARD IN EACH SEASON AND THE MEAN NUMBER OF SFERIC FIXES IN EACH "ONE DEGREE SQUARE".

\+ 48 GRID POINTS IN UNITED KINGDOM AT WHICH THE NUMBER OF THUNDER HOURS WAS INTERPOLATED.

o 17 STATIONS IN WEST GERMANY WHERE THE NUMBER OF THUNDER HOURS WERE TABULATED.

Fig 12 Areas used for comparison of thunder hours and sferic fixes.

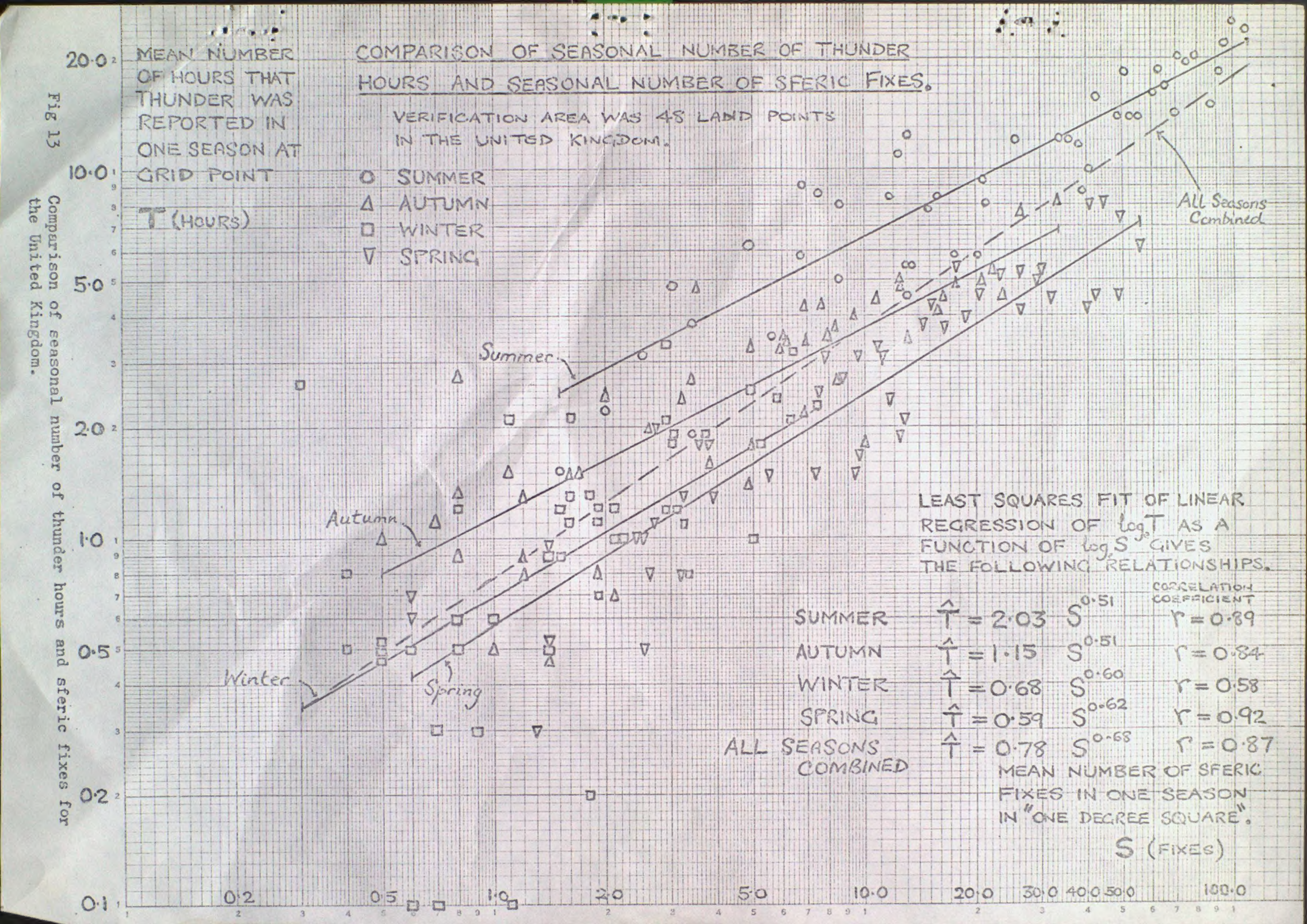


Fig 13 Comparison of seasonal number of thunder hours and sferic fixes for the United Kingdom.

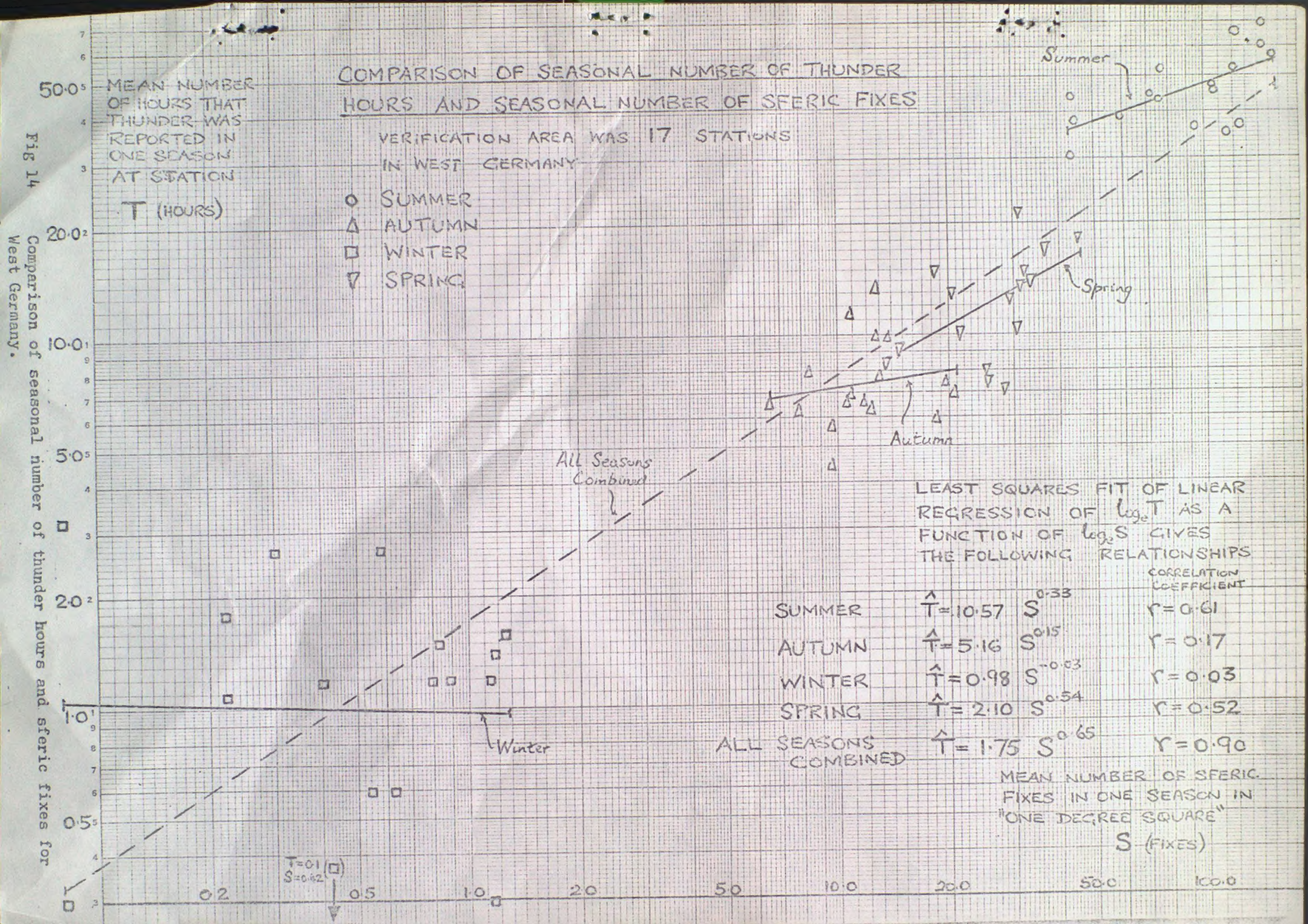


Fig 14 Comparison of seasonal number of thunder hours and sferic fixes for West Germany.